Study of Lead, Zinc, Silver and Copper
content of the Morrison and Twist Gulch Formation
Central Utah

by
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Approved by:

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ABSTRACT

The Twist Gulch Formation and the Morrison (?) Formation were studied as possible future sources of economic concentrations of copper, lead, zinc and silver. The content of these metals was determined by atomic absorption spectrophotometry.

The results of this study show that the area studied was depleted from silver and that the concentrations of copper, lead and zinc are not of economic proportions.

CONTENTS

INTRODUCTION

The district mapped lies in Sanpete County, along the eastern front of Gunnison Plateau, in Central Utah, see Figures 1 and 2. The area is bordered by Wales Canyon to the north, Petes Canyon to the south, Wasatch Plateau to the east and the Gunnison Plateau to the west.

Several works have been published which describe the coal beds near Wales, one of them by G.B. Richardson (1907). This report also dealt with the general geology of the area and its relations to underground in Sanpete and Sevier Valleys. In 1978 Craig Cox studied the areas southern of Sanpete Valley and eastern of Sevier Valley to determine the trace metal chemistry of the Arapien shale and the Twist Gulch Formations.

The purpose of this report is to determine the concentrations of lead, copper, zinc and silver in the Twist Gulch and Morrison Formation. The field work was done in summer of 1980 under the supervision of Dr. George Moore. The writer is indebted to Dr. Douglas Pride for his guidance during the preparation of this report and also to Lisa Koenig and Craig Cox who generously supplied information gained during their work.

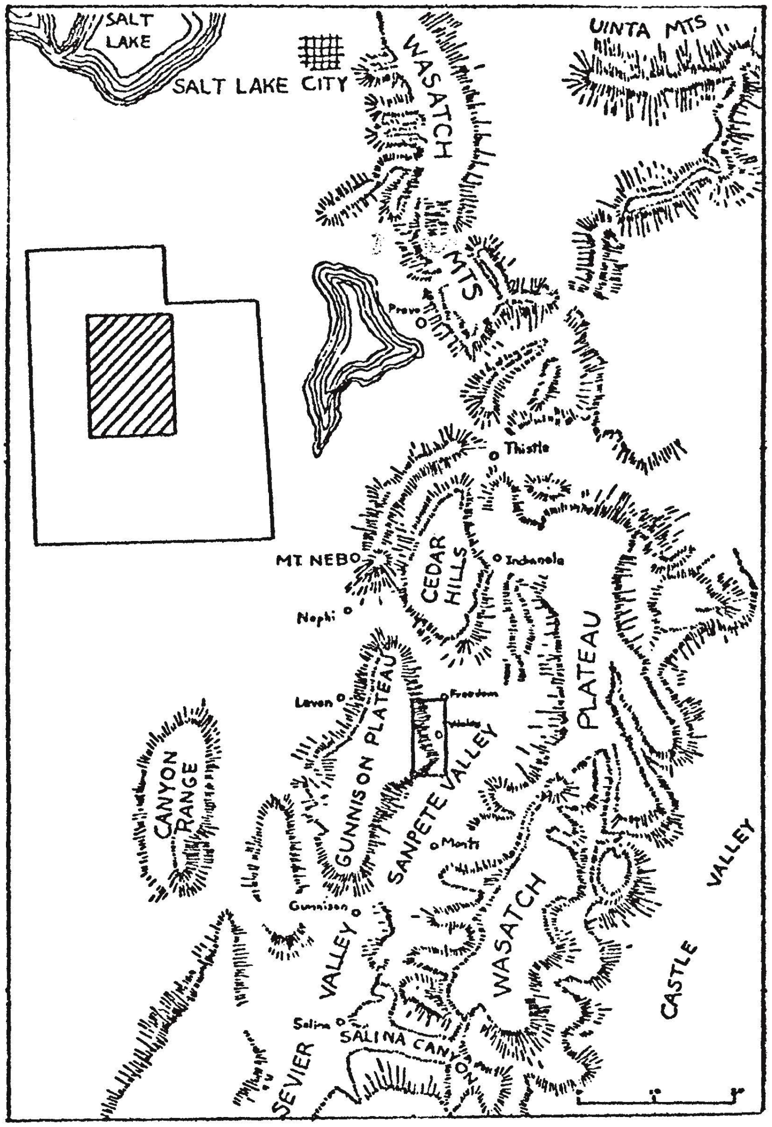


Figure 1. Index Map of Central Utah

(From Taylor, 1948)

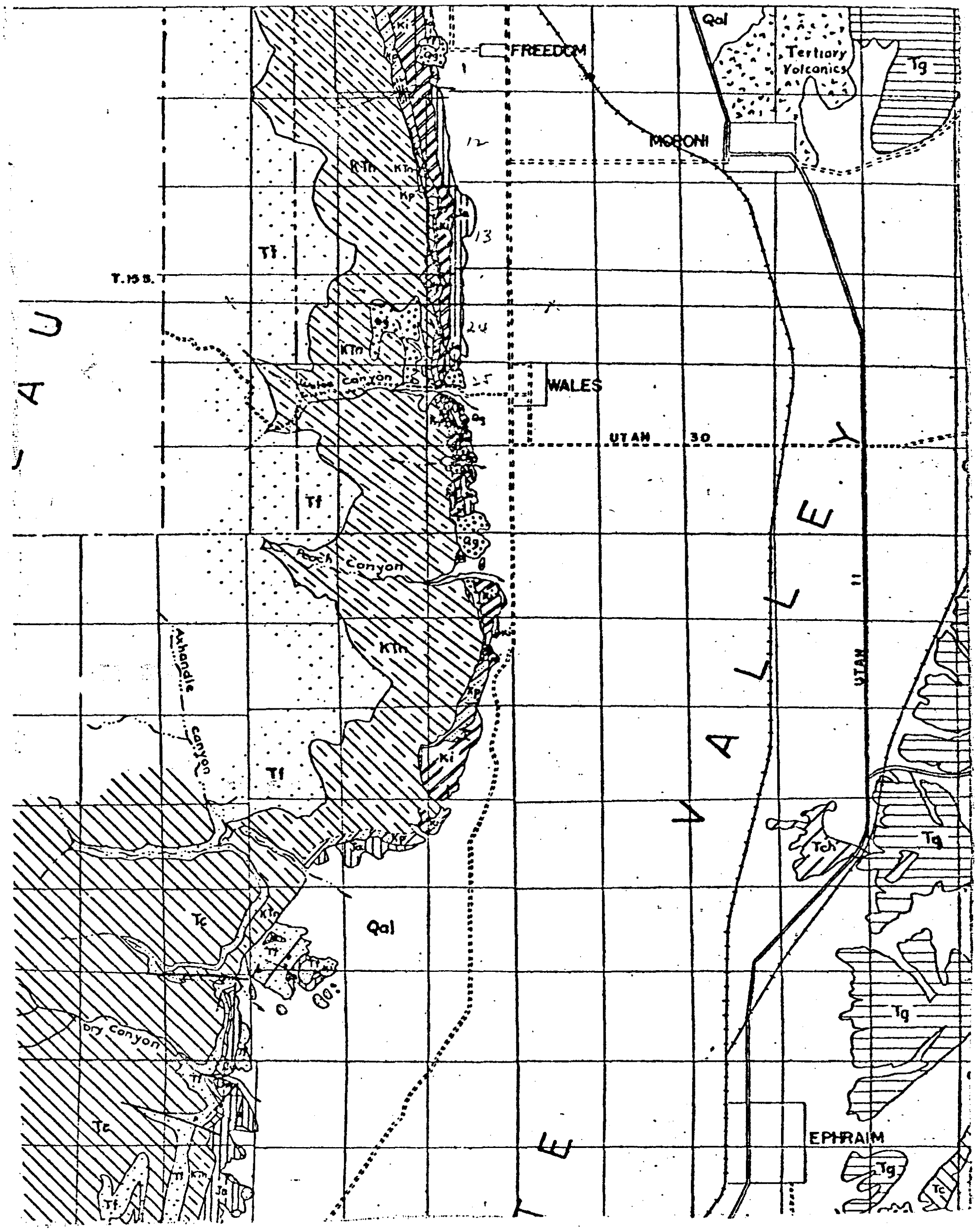


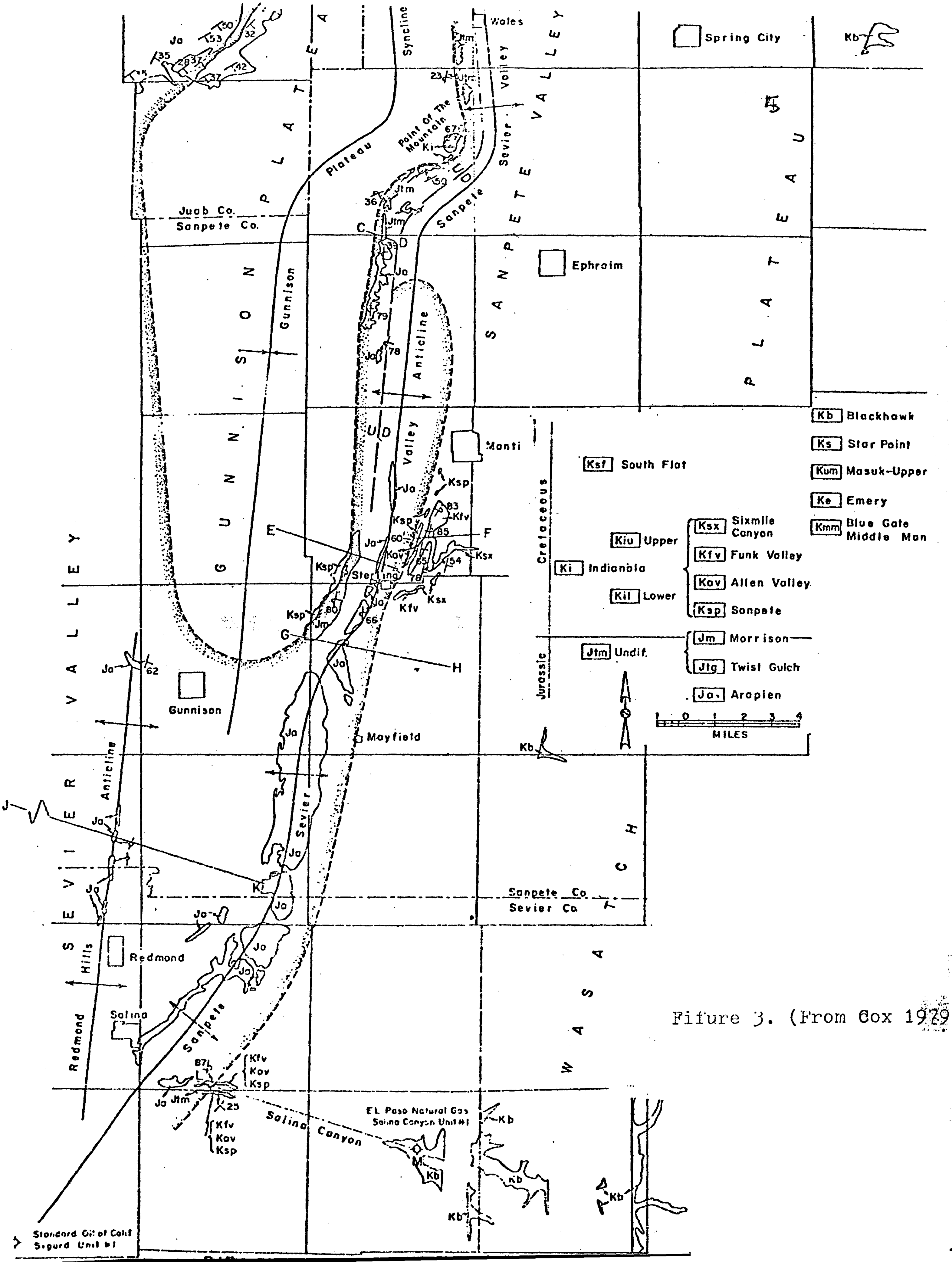
Figure 2.(From Spieker 1946)

MAJOR GEOLOGIC FEATURES

The Wasatch Plateau covers an area of 2300 square miles and is the northern most of the high plateaus of Utah. The western front of the plateau is a striking monocline whose block faulted slopes bend down from altitudes of 10,000 feet to 50,000 feet in a sweeping arch. This monocline extends from Salina to the vicinity of Fairview, where the monocline gives to a fault (Wilson, 1949). The faulting probably occurred in late Eocene or Miocene time (Spieker, 1930). Parallel to and just west to the plateau front is the Sanpete Valley anticline. This is probably the major structural feature of the area (Fig.3). This is a northerly-plunging anticline 65 to 70 miles long (Cox,1978).The western side of the valley is bounded by the steep cliffs of the eastern margin of the Gunnison Plateau (Wilson, 1949). A major structural event in Paleocene when normal faulting, produced the Plateau(Spieker,1949).

STRATIGRAPHY

In 1949 Spieker recognized the existence of two sedimentary provinces in Central Utah: an eastern province in which facies are essentially cratonic, and a western province in which the facies are geosynclinal accumulations related to orogenic impulses. The Gunnison Plateau is composed of units representing the western facies. Sedimentary deposits from medial Jurassic to late Tertiary or early Quaternary time reflect clearly the geosynclinal nature of the area during the Jurassic and Cretaceous periods and the orogenic movements of the late Mesozoic-early Cenozoic interval. This facies differs mainly from the eastern



Fifure 3. (From Cox 1979

or cratonic facies in having thicker more clastic sediments (Hunt, 1950).

The Navajo sandstone, Arapien shale, Twist Gulch Formation, and Morrison (?) Formation, all of Jurassic age, and the Upper Cretaceous Indianola group are overlain unconformably by the Price River Formation also of Upper Cretaceous age (Spieker, 1946). The North Horn Formation of Upper Cretaceous to Paleocene age lies conformably on the Price River Formation. These formations are overlain conformably by the Flaggstaff Limestone, and the Colton, Green River, and Crazy Hollow formations, all of Eocene age. The area is capped by the Axtel Formation which overlaps most of the older units and is composed largely of locally derived material (Cox, 1979). This is illustrated in Figure 4, and in Tables 1 and 2.

Twist Gulch Formation

Definition

The Twist Gulch Formation was defined by Spieker in 1946 as a member of the Arapien shale. In 1949 Hardy and Spieker redesignated the unit as a formation.

Distribution

The Twist Gulch Formation is rather widespread near its type locality east of Salina, Utah, along the eastern margin of the Sevier Valley, and along the eastern margin of the Gunnison Plateau. On the west side of the plateau it occurs in a narrow belt at the base of the Huracaine cliffs (Hunt, 1950). Farther north, near Wales, it appears beneath steeply dipping Indianola strata. Other areas of distribution through Central Utah have been widely discussed by Hunt, Taylor and Hardy.

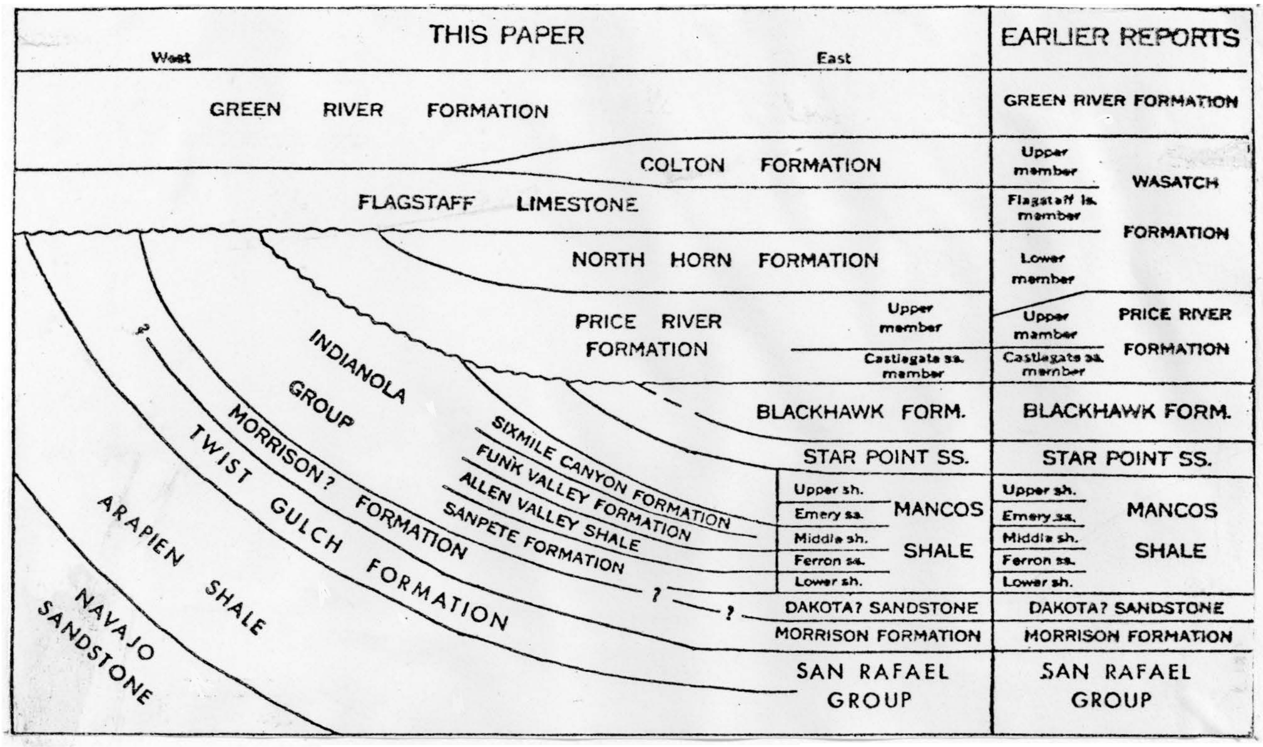


Figure 4.(From Cox,1979)

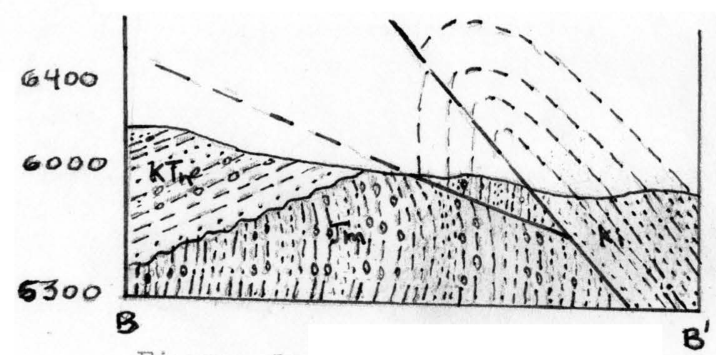


Figure 5.

Table 1 (From Cox 1979)

Age		San Rafael Swell	Central Utah	Southwest Utah	Central Wasatch Mountains	Southern Wasatch Mountains	Southeastern Idaho
Cretaceous		Morrison	Morrison (?)	Absent	Morrison	Morrison	? Ephraim Conglomerate
Upper Jur.	San Rafael gp.	Summerville	Twist Gulch		Twin Creek Limestone		
		Curtis / Moab Ss. mbr.		Curtis		? Curtis	? Stump
							Absent
		Entrada		Entrada		Entrada	Preuss
		Carmel	Arapien Shale	Carmel		Twin Creek Limestone	?
Jurassic	Glen Canyon gp.	Navajo Sandstone	Navajo Sandstone	Navajo Sandstone	Nugget Sandstone	Nugget Sandstone	? Absent
		Kayenta	?				Nugget Sandstone
Triassic		Wingate Sandstone		Absent	Absent		
		Chinle		Chinle	Ankareh		

Table 2 (From Cox 1979)

AGE		FORMATION	CHARACTER	THICKNESS (Feet)
TERTIARY		Axtell	Conglomerate, gravel	Unknown
		Unconformity		
		Lava flows	Trachyte and related rocks	0-500+
		Unconformity		
		Pyroclastic rocks	Gray sandstone, buff limestone, shale, bentonite, volcanic ash	0-700+
		Unconformity		
	Eocene	Crazy Hollow	Gray sandstone, red shale	0-600+
	Eocene	Green River	Green-gray shale, buff limestone	0-800+
	Eocene	Colton	Red and green-gray shale	0-300+
	Paleocene(?)	Flagstaff	Gray limestone and shale, red siltstone, conglomerate	0-800+
		Local Unconformity		
	Paleocene	North Horn	Not present in mapped area.	
CRETACEOUS	Upper Cretaceous	Price River	Not present in mapped area.	
		Unconformity		
	Upper Cretaceous	Indianola group	Brown sandstone, conglomerate	7,000+
JURASSIC	Upper Jurassic	Morrison (?)	Conglomerate, gray sandstone variegated shale, limestone	300-1,000
	Upper Jurassic	Twist Gulch	Red siltstone, reddish-gray sandstone	3,000
	Upper Jurassic	Arapien Shale	Gray-to-red sandstone and shale	5,000-7,000
	Upper Jurassic	Navajo Sandstone	Buff aeolian sandstone	Unknown

Lithologic character and thickness

The Twist Gulch Formation is characterized by reddish or gray clastic sediments. The assemblage of siltstone, sandstone and grit is constant throughout Central Utah and recognition of the unit is easy (Hunt, 1950). Shales in the Twist Gulch are gray, blocky non calcareous, and pebbly in part. The sandstones range from fine to course, grained and massive, well cemented and ripple marked. The grits are easily discerned by their massive, friable nature which results in rounded, ledge-like weathering forms (Hunt, 1950).

In parts of Central Utah the unit contains vainlets of gypsum. This is not true in most of the Gunnison Plateau (Hunt, 1948).

Spieker in 1941 reported a maximum thickness of 3,000 by assuming a straightforward succession to the fault inasmuch as the beds on both sides of the fault are nearly vertical and parallel in strike. Thicknesses of 1800-1900 feet thick were reported in the west side of the plateau by Zeller in 1948. Thicknesses of 1200 to 956 feet thick were reported by Taylor and Hunt in 1948.

Age

The Twist Gulch Formation is considered by Hardy (1949) as Upper Jurassic, equivalent to the Entrada, Curtis and Summerville formations of the San Rafael group of east-central Utah, but Bayley(1950) considers it partly equivalent to the Morrison Formation of the San Rafael Swell. It may be also partly equivalent to the Buckhorn conglomerate of lower Cretaceous age in San Rafael Swell (Hunt, 1950).

Morrison(?) Formation

Definition

In Salina Canyon, at Thistle and along the eastern front of the Gunnison Plateau, section of rocks occur in a stratigraphic position similar to that of the San Rafael Morrison. Spieker (1946) designated these beds as the Morrison(?) Formation because definite evidence that they are Morrison is lacking.

Distribution

In the vicinity of the Wasatch and Gunnison Plateaus of south-central Utah, continental beds of Morrison aspect are exposed in a few localities, where the stumps of the Late Cretaceous mountains have been bared by erosion. Spieker (1946) who studied the Morrison-like beds in some detail designated them Morrison(?) Formation, especially those exposed in Lake Fork near Thistle, Utah, and in Salina Canyon near Salina, Utah. (These areas are north and south of the area covered in this paper). A number of exposures of these rocks on the east and west flanks of the Gunnison Plateau have come to be regarded as Morrison(?); in recent years. The type locality of this Formation is in Colorado.

Lithologic character and thickness

Varicolored mudstones, interbedded stream channel sandstones and conglomerates, lacustrine limestones comprise the distinctive lithologies of this formation (Hitze, 1973).

The thickness of the Morrison(?) varies greatly from place to place. It is as much as 850 feet, although at most places it is less (Baker et.al.1936). There are places where has registered 1800 feet and 1300 feet respectably (Bayley, 1950).

Age

Several writers have assigned the beds here included in the Morrison(?) Formation an age widely different in one area from that assigned in another area.

There strata are transitional between rocks of Upper Jurassic age and rocks of Upper Cretaceous age, in regional terminology, they lie between the Twist Gulch Formation and the lower part of the Indianola group (Frazier, 1951).

GEOLOGIC HISTORY OF WALES GAP

Deposition of Twist gulch, limestone and mudstone occurred during Jurassic time, in shallow waters. Morrison(?) sandstones, mudstones and conglomerates were deposited in later Jurassic as the region began to be uplifted. Uplift continued as proven by the gradual change from Twist Gulch sandstones and mudstones to deposition of Indianola sandstones and conglomerates. After the deposition of the Indianola, the beds were folded, eroded and tilted. Later on during Cretaceous time the Price River was deposited by a river as a channel conglomerate. It was deposited unconformably on the Indianola. The beds were dipping westerly at this time. The North Horn beds were deposited on top of the Price River as a fresh water unit with much Lithologic variability. After deposition of the North Horn, tilting occurred again. The unconformity occurred sometime during Cretaceous time. Thrust faulting began to occur after the deposition of the North Horn and the tilting of the beds probably occurred during late Tertiary time. Faulting and erosion of the formations has continued through recent time. For illustration of this process see Figures 4 and 5.

Field Studies

Field studies were conducted during the summer of 1980. Samples 1 through 14 were collected from the area shown in Fig. 7 which is located south of Wales Canyon. Most of the samples collected consisted of small chips which were collected as warranted by significant Lithologic changes and by using the Jacob rod method.

Analytical Results

The samples collected in the Morrison(?) Formation were completely depleted from silver, partially depleted from copper, subtly enriched with zinc and very enriched with lead. Zinc and lead were present in all of the samples, copper was present in some and silver did not show at all (see Table 3).

The samples collected in the Twist Gulch Formation were completely depleted from silver and copper, but all of them show zinc and copper concentrations. Both formations show high concentrations of lead (see Tab. 3). The results of these analyses are shown in tables 3 through 10.

Interpretation of Results

The fact that the Morrison(?) Formation is entirely continental in origin and it was deposited by intermittent shifting streams and under possible semiarid conditions during the withdrawal of marine waters, while the Twist Gulch is entirely marine deposits may have something to do with the presence of copper in the Morrison(?) Formation. The Morrison conditions may represent a sabkha-type model of mineralization as described by Cox (1979). This is just a possibility because the genesis of ore deposits is a subject on which geologists have long differed, perhaps because the deposits at different localities have had different modes of origin (Butler et.al., 1920).

Hitze said in 1973 that the mudstone beds in the Morrison (?) Formation include much reworked volcanic ash and that the conglomerates in central Utah were certainly derived from the

Table 3

	Morrison Formation			Twist Gulch Formation		
	Cu	Pb	Zn	Cu	Pb	Zn
Mean	132	433	41	–	403	79
Median	106	347	46	–	336	76
Mode	–	340	–	–	347	–
Range	100 - 190	327 - 971	20 - 58	–	304 - 829	55 - 114

Sevier Orogenic Belt in western Utah. An igneous source was suggested for the Twist Gulch by Cox in 1979. This could indicate that metallic minerals were later than the sandstones and were deposited by mineralizing solutions whose circulation was connected with the igneous activity of the region.

The high concentration of lead in both formations indicates that their sources were enriched with this element which probably was transported as a sulfide or a sulfate.

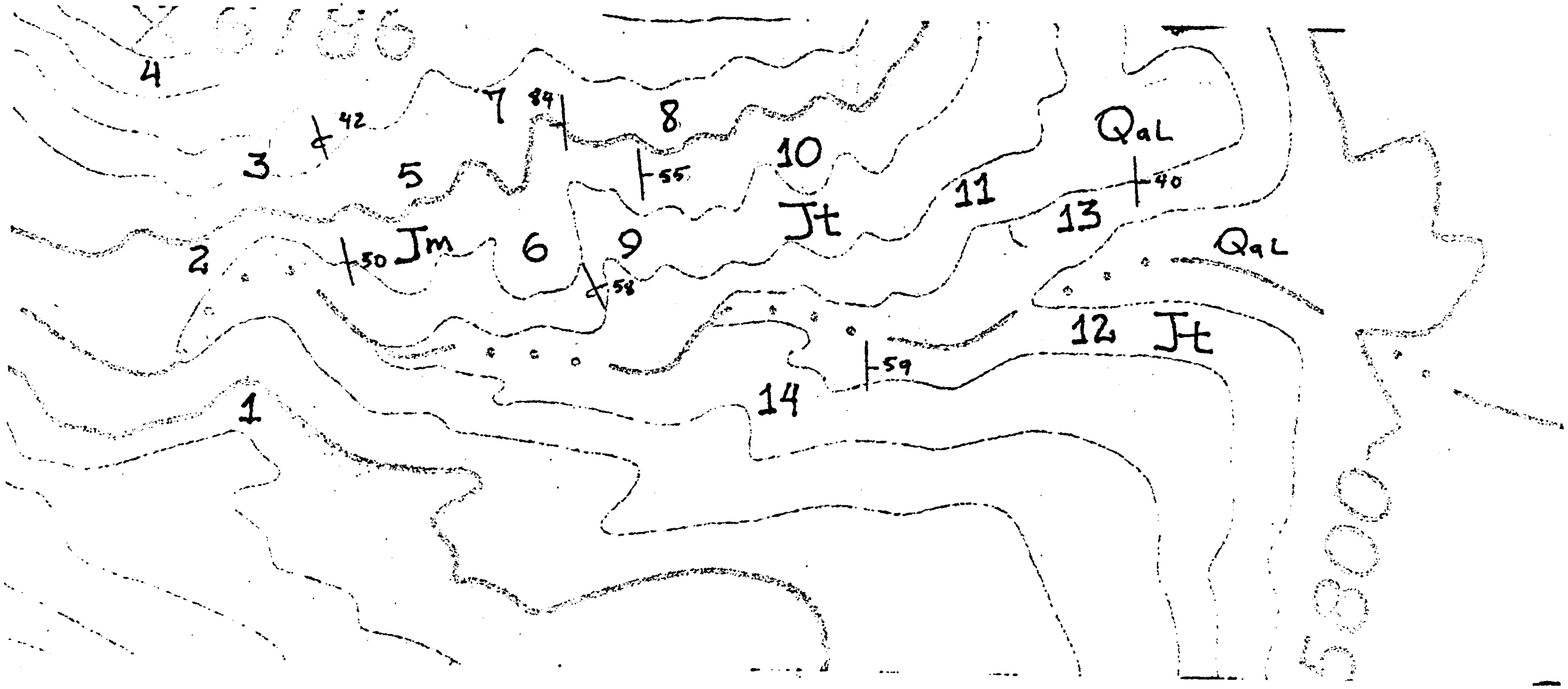


Fig. 6 Samples Location

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APPENDIX A: ATOMIC ABSORPTION ANALYSIS

General Procedure

Samples were collected in the field and then they were brought to the laboratory in order to grind them and test them for con-centrations (in ppm) of copper, lead, zinc, and silver. The samples were ground approximately to clay size and then were stored in numbered boxes. About 0.5 grams of sample was weighed and placed in a Teflon beaker with 10 ml. of Hydrofluoric acid, 4 m. of carbonated Nitric acid and 3 ml. of concentrated Hydrochloric acid, the mixture was gently heated to dryness. The residue was then taken into solution by adding 50 ml. of 10% Nitric acid. This solution was gently heated until the residue was dissolved. Then it was transferred to a 100 ml. volumetric flask, it was allowed to cool and then it was brought to volume by addition of more 10% Nitric acid. These solutions were stored in 125 ml. plastic bottles for analysis. This procedure was obtained from Cox (1979).

Standard solutions were also prepared for copper, lead, zinc, and silver by using:

$$\text{ml. of stock required} = \frac{\text{concentration of dilute standard} \times \text{volume of dilute standard}}{\text{stock solution concentration}}$$

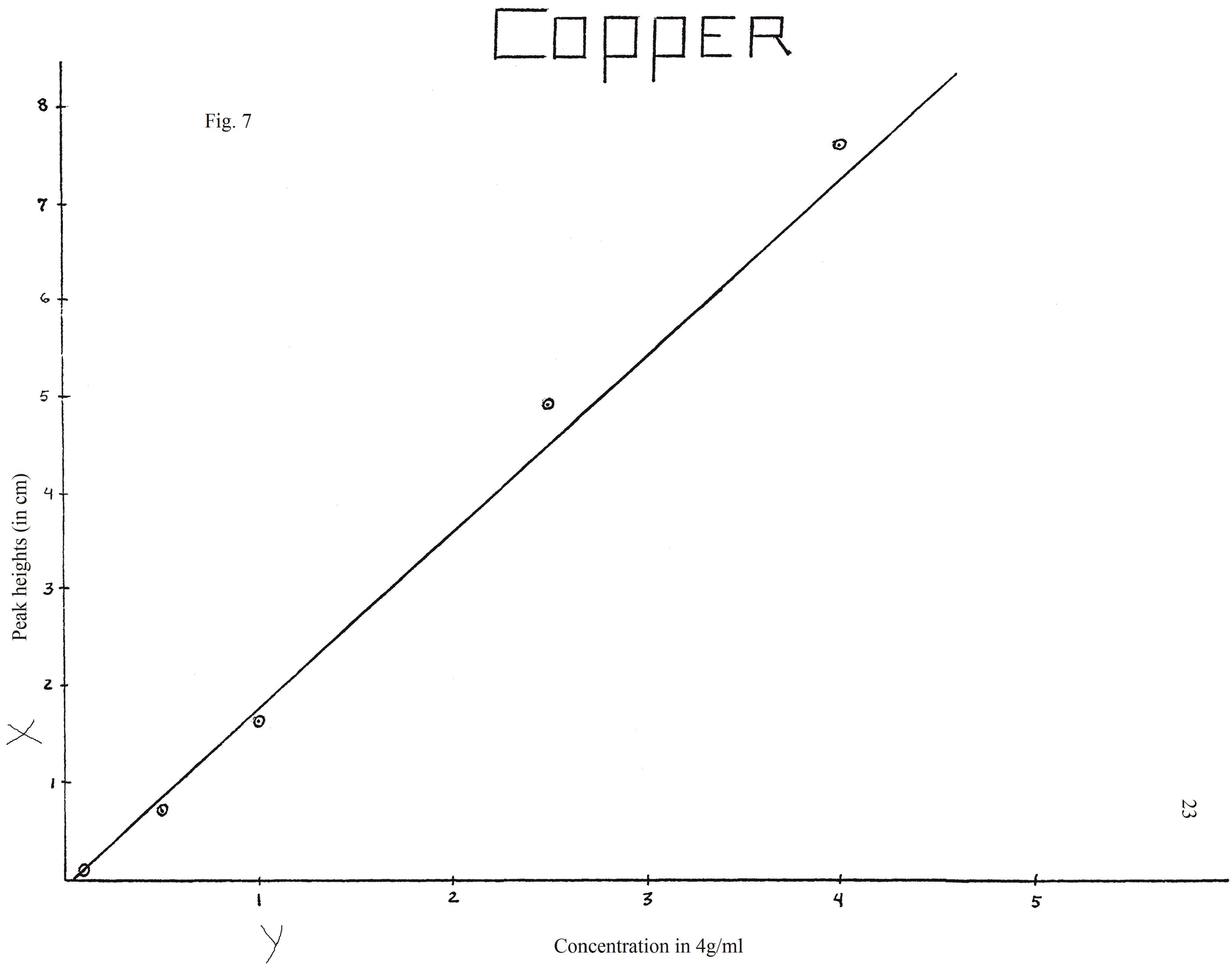
Blanks were also prepared in order to check any traces in the acids or water used.

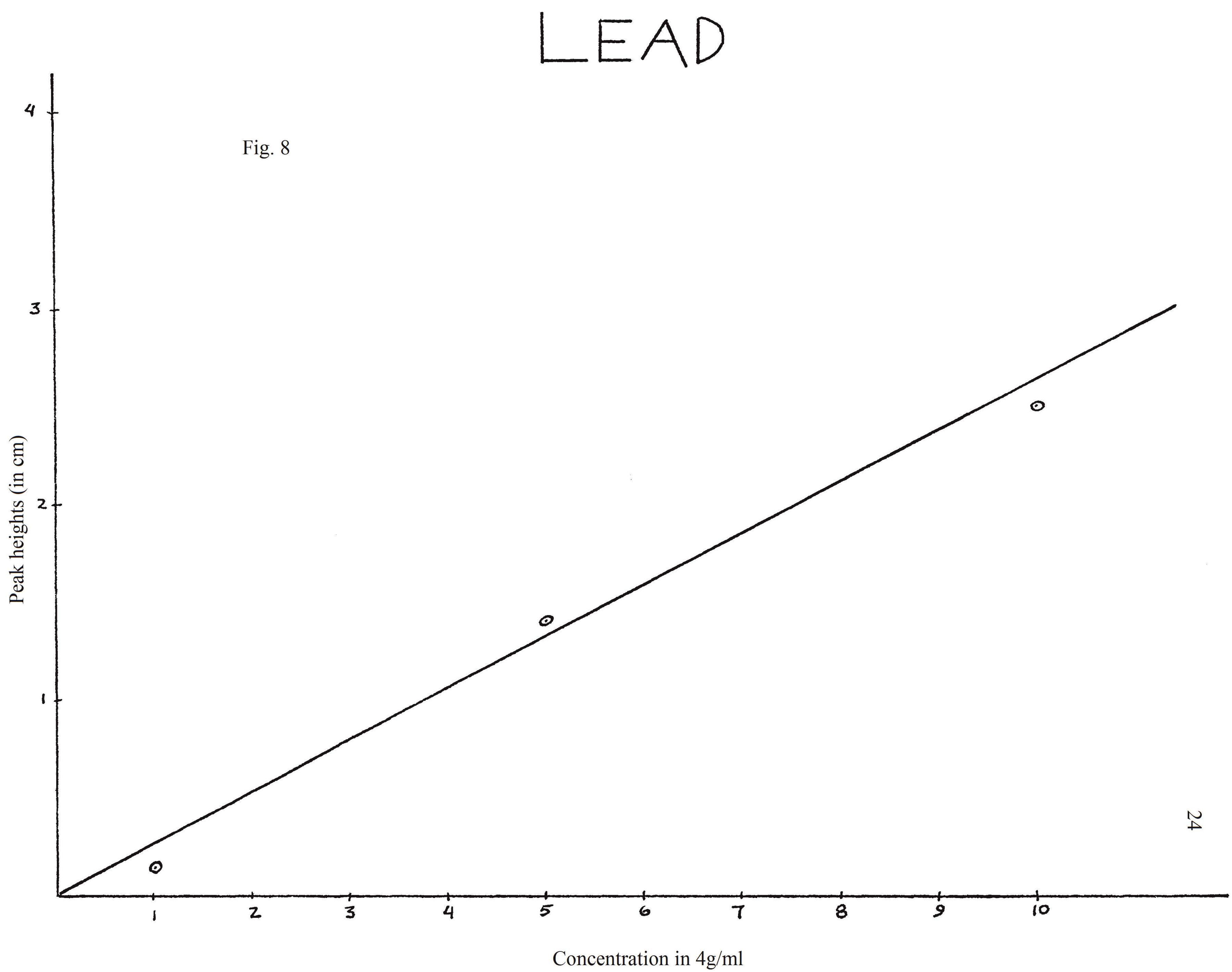
The standards, the samples and the blanks were analyzed for copper, lead, zinc, and silver by atomic absorption spectrophotometry. a Perkin-Elmer 303 atomic absorption spectrophotometer equipped with the Perkin-Elmer 165 strip chart recorder and the appropriate hollow cathode tubes was used. Curves with the respective peak heights were obtained for each element.

Data and Calculations

To calculate the concentration C of each sample, the slope of the curve was obtained for each element. To get the slope, linear regression and the formula $y=mx+b$ were used; where y=peak heights, m=slope, x=standard concentration and b=intercept. The slopes of these curves were plotted in Figures 7 through 10. The concentration C in 4g/ml can be obtained from the curve or by using linear regression.

To calculate concentration in ppm the formula ppm=C.V. of /W was used. In this formula ppm is concentration in parts per million, C is concentration in 4g/ml, Vis the volume; in this case 100 ml., d.f. is the dilution factor if used, and W is the weight of sample. For data and calculations see tables 3 through 10.


Copper
Fig. 7
Peak heights (in cm)
8
7
6
5
4
3
2
1
1
2
3
4
5
X
Y
Concentration in 4g/ml


LEAD
Fig. 8
4
3
2
1
Peak heights (in cm)
1
2
3
4
5
6
7
8
9
10
Concentration in 4g/ml

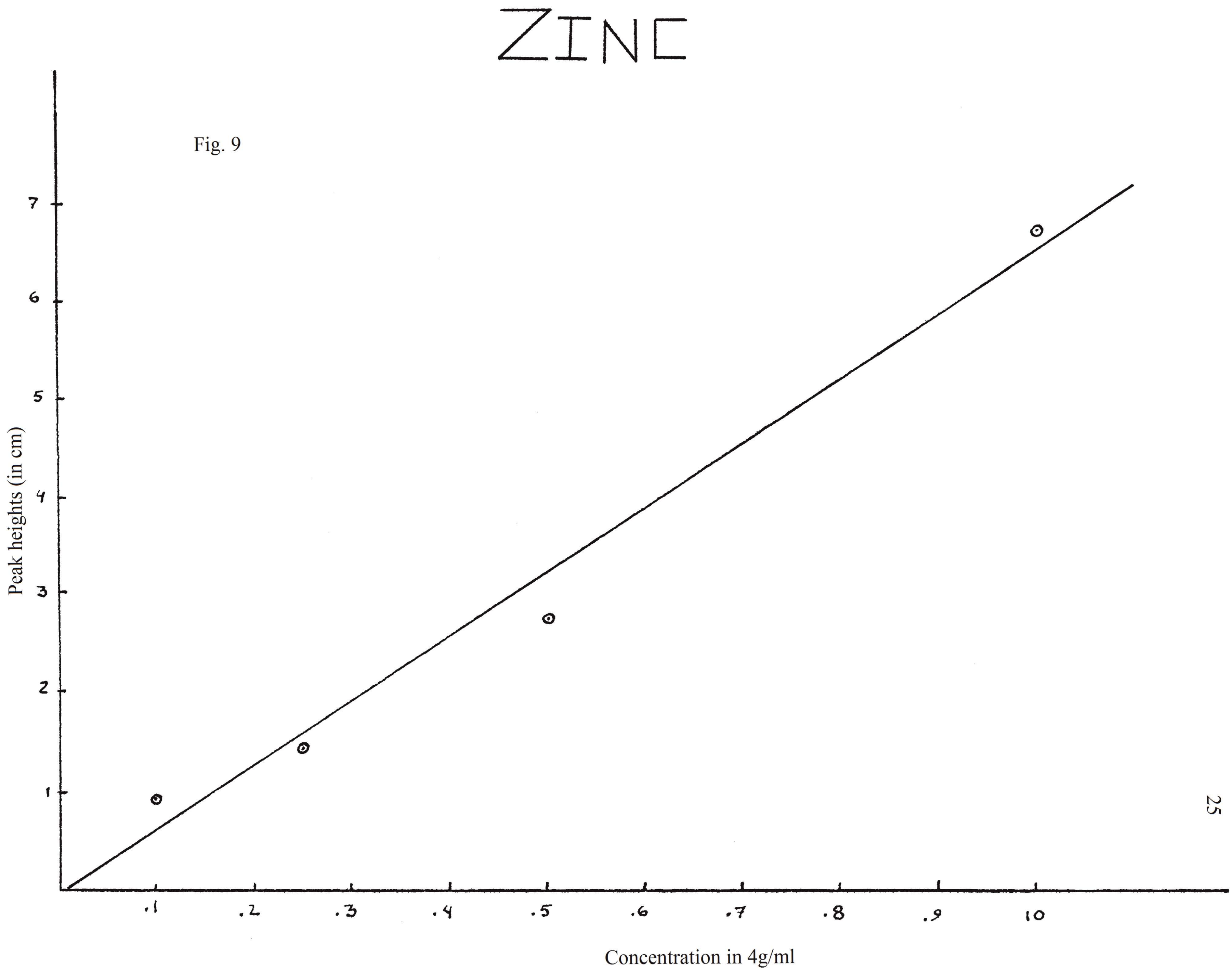
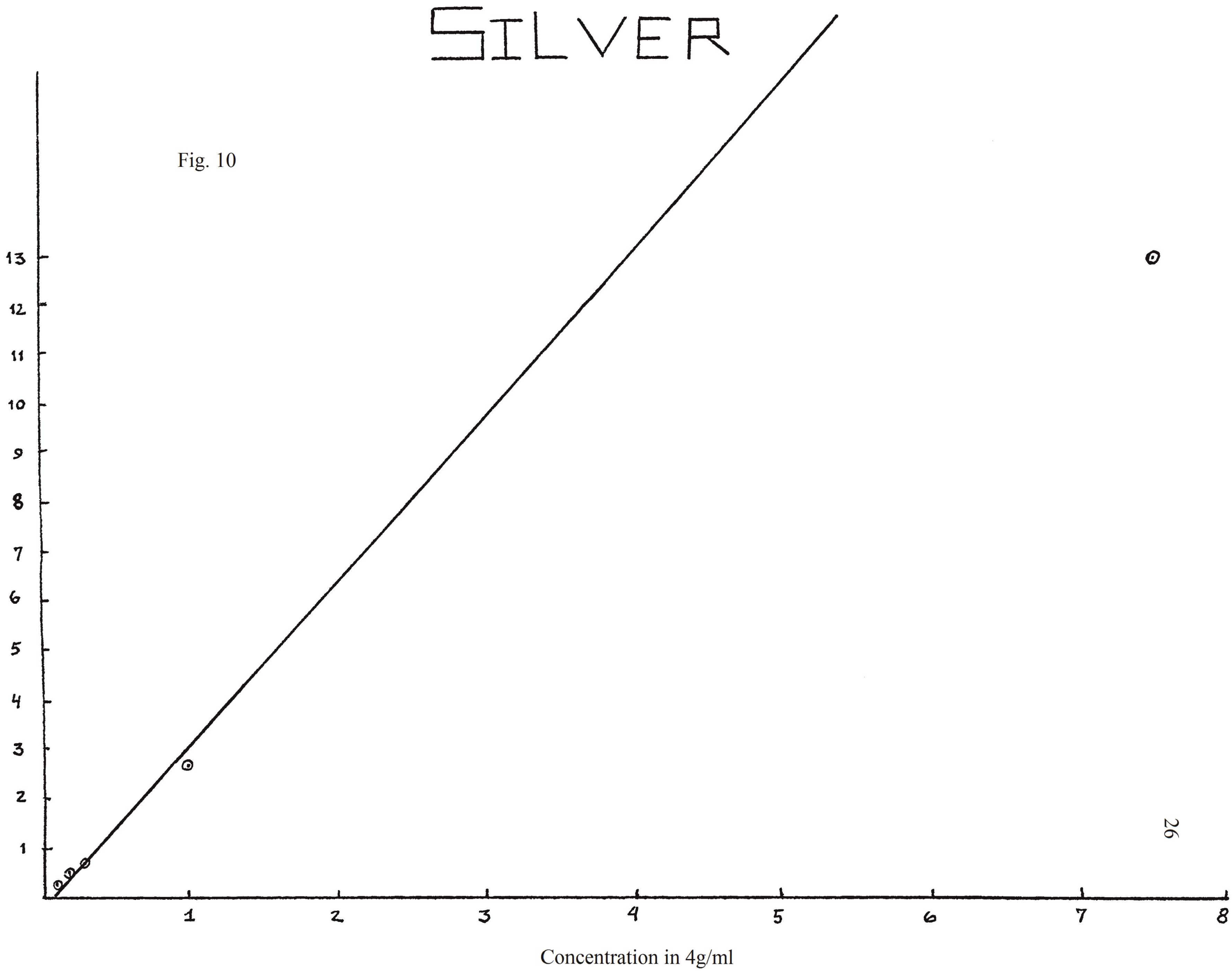

ZINC
Fig. 9
Peak heights (in cm)
1
2
3
4
5
6
7
.1
.2
.3
.4
.5
.6
.7
.8
.9
10
Concentration in 4g/ml

Fig. 10


SILVER
13
12
11
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
Concentration in 4g/ml

APPENDIX B: ANALYTICAL RESULTS PER SAMPLE

The analytical results per sample for copper, lead, silver, and Zinc are shown in tables 4 through 10.

Table 4. Analytical results for copper standards

Standard Concentration (ppm)	Peak height (cm)	Slope	Intercept
.1	.1		
.5	.7		
1.0	1.6	1.573	.116
2.5	4.9		
5.0	7.6		

Table 5. Analytical results for copper samples

Sample	Weight (gr)	Peak height (cm)	C (g/ml)	ppm
1	.41	1.35	.78	190
2	.48	–	–	–
3	.49	–	–	–
4	.52	–	–	–
5	.55	–	–	–
6	.50	–	–	–
7	.49	–	–	–
8	.48	–	–	–
9	.52	–	–	–
10	.50	.20	.53	106
11	.56	–	–	–
12	.53	.20	.53	100
13	.49	.25	.09	17
14	.50	–	–	–

Table 6. Analytical results for lead standards

Standard concentration (ppm)	Peak height (cm)	Slope	Intercept
1.0	.15		
5.0	1.4	.259	-.034
10.0	2.5		

Table 7. Analytical results for lead samples

Sample	Weight (gr)	Peak height (cm)	C (g/ml)	ppm
1	.41	1.0	3.98	971
2	.48	1.0	3.98	829
3	.49	.40	1.87	345
4	.52	.40	1.87	327
5	.55	.45	1.86	338
6	.50	.40	1.87	340
7	.49	.40	1.70	347
8	.48	.40	1.70	354
9	.52	.40	1.70	327
10	.50	.45	1.80	360
11	.56	.40	1.70	304
12	.53	.40	1.70	321
13	.49	.40	1.70	347
14	.50	.40	1.70	340

Table 8. Analytical results for zinc standards

Standard concentration (ppm)	Peak height (cm)	Slope	Intercept
.1	.9		
.25	1.45	6.663	-.105
.5	2.75		
1.0	6.75		

Table 9. Analytical results for zinc samples

Sample	Weight (gr)	Peak height (cm)	C (g/ml)	ppm
1	.41	.45	.084	20
2	.48	2.8	.44	92
3	.49	3.6	.56	114
4	.52	1.5	.24	46
5	.55	1.85	.29	53
6	.50	.83	.14	28
7	.49	2.8	.44	90
8	.48	1.4	.23	47
9	.52	2.35	.37	71
10	.50	1.15	.19	38
11	.56	1.85	.29	58
12	.53	1.8	.29	55
13	.49	2.35	.37	76
14	.50	1.85	.29	58

Table 10. analytical results for silver standards

Standard concentration (ppm)	Peak height (cm)	Slope	Intercept
.1	.25		
.2	.5		
.3	.7	1.698	.339
1.0	2.7		
7.5	13		

APPENDIX A

Atomic Absorption Analysis

General Procedure

Copper, lead, zinc, and silver concentrations were determined at The Ohio State University using a Perkin-Elmer model 303 atomic absorption spectrophotometer, and the data were recorded by a Perkin-Elmer model 165 strip-chart recorder. An air-acetylene flame was used in all analyses. Instrument settings, air-acetylene flow rates, and methods for data reduction were adapted from the Perkin-Elmer Methods Handbook (1971 edition).

Standard stock solutions were purchased from VWR SCientific Company, Columbus, Ohio. Appropriate dilutions were made from the stock solutions to generate the standard working curves. The working curves, generated by least squares regression, and the correlation coefficients for each of the elements are shown respectively in figures A-1, A-2, A-4 and A-6. All of the curves are linear through the range of the stock standard dilutions. The extreme low ends of the lead, zinc, and silver curves were made to pass through the origin to avoid negative concentrations at very low peak heights. These curves are shown in figures A-3, A-5, and A-7. The low values for the copper working curve so closely approached the origin that a modified curve was not necessary.

The concentration of a metal in a sample was calculated from the following equation:

$$\text{ppm} = \frac{(C) \quad (V) \quad (d.f.)}{(W)}$$

where C is the concentration of the metal, in ™g/ml of sample solution (obtained from the appropriate working curve); V is the original volume of the sample solution in ml; d.f. the dilution factor (if dilution is necessary to obtain a relative height within the range of the working curve); and W the weight in grams of rock powder used in preparing the sample solution.

Duplicate samples were run to check the reproducibility of the data; and U.S.G.S. standard rock powders were run to check the accuracy of the analytical procedures and of the equipment used in the analyses. The standard solutions were run at the beginning, midway point, and end of each analytical session.

Gold contents were analyzed by atomic absorption to 0.001 ppm by Skyline Labs., Inc., of Wheat Ridge, Colorado.

The results of the atomic aborption analyses are given in Appendix D.

Sample Preparation*

Rock-chip samples were reduced to a fine powder in a Spex Industries shatterbox ring grinder equipped with an alumina grinding head. Approximately 0.5 grams of each sample was weighed to the nearest 0.1 mg and placed into a 100 ml teflon beaker; and 10 ml of

*Modified after Warlow (1978)

concentrated hydrofluoric acid, 4 ml of concentrated nitric acid, 3 ml of concentrated hydrochloric acid, and 2 ml of concentrated sulfuric acid were added to the beaker. This mixture was then placed on a hot plate under a fume hood at 75°C and left overnight to dry. The residue then was taken into solution by adding approximately 50 ml of 10% v/v nitric acid and heating on the hot plate for 10-20 minutes. This solution was transferred to a 100 ml volumetric flask, allowed to cool, and brought to volume with 10% v/v nitric acid. The solutions were stored in 125 ml screwtop plastic bottles.

For the gold analyses, a portion of the rock powders from each sample was mailed to Sklyline Labs., Inc., Wheat Ridge, Colorado.